[0021] **FIGS. 11A-11G** are plots showing examples of signals used to drive a haptic device, according to an embodiment of the invention.

[0022] **FIGS. 12A-12C** are plots showing examples of signals used to drive a haptic device, according to an embodiment of the invention.

[0023] **FIGS. 13A-13E** are plots showing examples of signals used to drive a haptic device, according to an embodiment of the invention.

[0024] **FIG. 14** is a plot showing an example of a signal used to drive a haptic device, according to an embodiment of the invention.

[0025] **FIG. 15** is a diagram illustrating elements of an embodiment of the invention.

[0026] **FIG. 16** is a plot showing an example of a signal used to drive a haptic device, according to an embodiment of the invention.

[0027] **FIG. 17** is a plot showing an example of a signal used to drive a haptic device, according to an embodiment of the invention.

[0028] **FIGS. 18A-18C** are plots showing examples of signals used to drive a haptic device, according to an embodiment of the invention.

[0029] **FIG. 19A** is a plot showing an example of a step signal used to drive a haptic device and the corresponding response of the haptic device, according to an embodiment of the invention.

[0030] **FIG. 19B** is a plot showing an example of a signal used to drive a haptic device and the corresponding response of the haptic device, according to an embodiment of the invention.

[0031] **FIG. 20A** is a plot showing an example of a step signal used to drive a haptic device and the corresponding response of the haptic device, according to an embodiment of the invention

[0032] **FIG. 20B** is a plot showing an example of a signal used to drive a haptic device and the corresponding response of the haptic device, according to an embodiment of the invention.

DETAILED DESCRIPTION

[0033] Systems and methods for controlling multi-mode haptic devices are described. More specifically, an embodiment of the invention is described in the context of a haptic device that has a multiple operational modes, each of which is associated with a frequency range. A controller is coupled to the haptic device and is configured to send the haptic device multiple control schemes associated with the multiple operational modes.

[0034] Feedback provided via a haptic device is sometimes referred to as vibrotactile feedback or kinesthetic feedback, and is referred to more generally herein as "haptic feedback." Such haptic feedback can be provided, for example, by way of a haptic device or an interface device including a haptic device. Interface devices that provide haptic feedback can provide physical sensations that can be measured by some metric (e.g., perceivable frequency content), and can be felt by a user using a controller or manipulating a physical object of the interface device.

[0035] According to an embodiment of the invention, a haptic device has multiple operational modes. A first operational mode is associated, for example, with a high-frequency range, and a second operational mode is associated, for example, with a low-frequency range control scheme associated with each of the operational modes can be sent to the haptic device; each of the control schemes can cause the haptic device to provide a particular haptic feedback. The control scheme associated with each frequency range can be combined (e.g., superimposed, added, multiplied, convolved, combined by a non-vectored operation, etc.) with one or more remaining control schemes, or otherwise operated on, according to pre-determined rules to provide a transitional response between the frequency ranges. In this manner, an embodiment of the invention provides for a "blending" or "transitioning" of haptic feedback from a low-frequency range to a high-frequency range such that the performance over and between the low- and high-frequency ranges is relatively seamless.

[0036] According to another embodiment of the invention, a haptic device having multiple operational modes is provided. The multiple operational modes of the haptic device include, for example, a low-frequency operational mode, a high-frequency operational mode, and a transitional operational mode, which is associated with frequencies between low frequencies associated with the low-frequency mode and high frequencies associated with the high-frequency mode. The low-frequency operational mode is sometimes referred to herein as "unidirectional" (e.g., unidirectional spinning of a rotational device), and the high-frequency operational mode is sometimes referred to herein as "harmonic" or "oscillating." The transitional operational mode is associated with a transitional frequency range that combines a superposed response of the unidirectional mode and the harmonic mode. The low-frequency operational mode is associated with, for example, frequencies up to approximately 10 Hz, and the high-frequency operational mode is associated with frequencies, for example, above approximately 10 Hz. A transitional frequency range associated with the transitional operational mode includes, for example, frequencies from about 5 Hz to about 25 Hz, where the low-frequency and high-frequency operational modes are associated with frequencies below and above the transitional frequency range, respectively.

[0037] **FIG. 1** is a block diagram of a system having a processor system **10** and an interface device, according to an embodiment of the invention. The system illustrated in **FIG. 1** includes a processor system **10** in communication with an interface device **20**. The processor system **10** can be, for example, a commercially available personal computer or a less complex computing or processing device that is dedicated to performing one or more specific tasks. For example, the processor system **10** can be a terminal dedicated to providing an interactive virtual reality environment, such as a gaming system, or the like.

[0038] The processor system **10** includes a processor **12**, which according to one or more embodiments of the invention, can be a commercially available microprocessor. Alternatively, the processor **12** can be an application-specific integrated circuit (ASIC) or a combination of ASICs, which